ABSTRACT

In this study the effect of adding natural polymer as a drag reducing agent on the pressure drop in pipes carrying aqueous media is studied. A closed loop circulation system is designed to test the efficiency of the natural polymer. The closed loop circulation system is consist of four testing point, transparent PVC pipe up to three meter and 1 inch internal diameter. The natural polymer used in this experiment is mucilage that is extracted from Halba seed. Halba or Fenugreek consists of the dried ripe seeds of a small, southern European herb known technically as *Trigonella foenum-graecum* L., a member of the family Fabaceae. The seeds contain up to 40 percent of mucilage causing them to be used in various poultices and ointments intended for external application. The efficiency of natural polymer in reducing the percentage of drag is calculated from the data taken from experiment. Different concentration of Halba mucilage is used to test the efficiency of the natural polymer in reducing the drag in pipes. The results shows that the natural polymer extracted from Halba seed can reduce pressure drop in pipes up to 62%. Using natural polymer extracted from plant in reducing drag in pipeline is a great success and has a high commercial value in the future. The advantage of using natural polymer is, they are renewable and environment friendly.

ABSTRAK

Objektif dalam menjalankan kajian terbaru ini adalah mengkaji keupayaan formulasi polimer asli yang bertindak sebagai agen pengurangan seretan yang berlaku di dalam aliran paip. System aliran paip tertutup digunakan untuk mengkaji keupayaan polimer asli untuk mengurangkan seretan dalam paip. System ini terdiri daripada paip pvc, dua biji buah pam dan empat titik pengujian. Polimer asli yang digunakan dalam eksperimen ini diekstrak dari biji Halba. Biji Halba atau dikenali sebagai Fenugreek dalam bahasa English ini berasal dari europa selatan dan dikategorikan dalam family Fabaceae. Biji Halba mengandungi 40% mucilage. Biji Halba ini banyak digunakan dalam masakan dan dalam perubatan tradisional. Kepekatan berbeza polimer asli digunakan dalam kajian ini untuk mengukur keupayaan polimer asli ini untuk mengurangkan seretan dalam paip semasa aliran air. Daripada keputusan yang diperolehi, pilmer asli dari biji Halba dapat mengurangkan seretan dalm paip sebanyak 62%. Pengunaan polimer asli sebagai agen pengurangan seretan dalam aliran paip adalah satu kejayaan dan ia dapat menggantikan polimer sintetik yang digunakan sekarang. Polimer asli Halba mempunyai potensi yang baik pada masa akan dating.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DRA	-	Drag Reducing Agent
% DR	-	Percentage of drag reduction
ppm	-	Part per million
L	-	Liters
m.	-	Meter
rpm.	-	Rotation per minute
Δpf	-	Changes in pressure drop
D	-	Diameter
DR	-	Drag reduction
Re/ N_{Re}	-	Reynolds number
ml.	-	Milliliter
g.	-	gram
mg.	-	milligram
kg.	-	kilogram

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Pipelines have been the backbone energy transport infrastructure in many regions of the world for many decades now and this situation will most likely continue into the future. Transporting these fluids through pipelines required pumping power.

When a liquid flows through a pipeline, shear stresses develop between the liquid and the pipe wall. This shear stress is a result of friction, and its magnitude is dependent upon the properties of the fluid, the speed at which it is moving, the internal roughness of the pipe, the length and diameter of pipe. Friction loss, also known as major loss, is a primary cause of energy loss in a pipeline system.

To reduce the friction and pumping cost, drag reducing agents polymers are used in pipelines. These additives interact with the turbulent flow processes and reduce frictional pressure losses such that the pressure drop for a given flow rate is less, or the maximum flow rate for a given pressure drop is larger. This phenomenon is commonly called drag reduction. It has been used in commercial oil pipelines, fire hoses, and storm sewers to increase the flow capacities of existing systems. It can also be used to reduce supply pressures, pumping costs, and/or pipe diameters for given flow capacities.

1.1.1 Characterization of Halba

Fenugreek consists of the dried ripe seeds of a small, southern European herb known technically as *Trigonella foenum-graecum* L., a member of the family Fabaceae. It is variously referred to as trigonella or as Greek hayseed. The seeds contain up to 40 percent of mucilage causing them to be used in various poultices and ointments intended for external application. The name fenugreek or foenum-graecum is from Latin for "Greek hay". Zohary and Hopf note that it is not yet certain which wild strain of the genus Trigonella gave rise to the domesticated fenugreek but believe it was brought into cultivation in the Near East. Charred fenugreek seeds have been recovered from Tell Halal, Iraq, (radiocarbon dating to 4000 BC) and Bronze Age levels of Lachish, as well as desiccated seeds from the tomb of Tutankhamen. Cato the Elder lists fenugreek with clover and vetch as crops grown to feed cattle. [1]

Figure 1.1 : HALBA seeds

The rhombic yellow to amber colored fenugreek seed, commonly called Methi, is frequently used in the preparation of pickles, curry powders and pastes, and is often encountered in the cuisine of the Indian subcontinent. The young leaves and sprouts of fenugreek are eaten as greens, and the fresh or dried leaves are used to flavor other dishes. The dried leaves (called kasuri methi) have a bitter taste and a strong characteristic smell.

HALBA tree

Figure 1.2 : Halba tree

Fenugreek plant is a quick growing annual leguminous herb about 2 feet in height. Leaves are light green in color. Plant stems are long and slender. Fenugreek leaves are tripartite, toothed, grey-green obovate leaves, 20-25 mm long. Fenugreek plant blooms white flowers in the summer. Fenugreek seed pods contain ten to twenty small, flat, yellow-brown, pungent, aromatic seeds. Fenugreek seeds are small and stony; about 1/8 inch long, oblong, rhomboidal, with a deep furrow dividing them into two unequal lobes. Fenugreek seeds have a strong aroma and bitter in taste. Plants mature in about four months. Traditionally, fenugreek grows best in well-drained loams with a low rainfall. Mild Mediterranean climates are most suitable. Fenugreek is commonly found growing in Mediterranean regions of southern Europe, where both the seeds and leaves are used primarily as a culinary spice. The seeds of the fenugreek herb are an effective nutritional supplement and have also been used by herbalists for many centuries for the health benefits it provides. [14]

The active constituents in fenugreek are alkaloids, lysine and L-tryptophan. It also contains steroidal saponins (diosgenin, yamogenin, tigogenin, and neotigogenin) and mucilaginous fiber which are believed to be responsible for many of the beneficial effects fenugreek exhibits. The chemical compounds found in fenugreek have the ability to aid the digestive process. Consequently, when taken with meals it is believed that fenugreek is able to slow down the rate at which sugars are absorbed into the body, whereby regulating blood sugar levels. Additionally, studies indicate that 4-hydroxyisoleucine (an amino acid) found in fenugreek may induce or promote the production of insulin when blood sugar levels are elevated. The table below shows the active constituent of the HALBA seed. [14]

1.1.2 The active constituent of HALBA seed

The composition of fenugreek seeds was extensively studied and their composition reveals a few specific features.

Table 1.1: The active constituents of Halba seed

Active Constituents	28% mucilage 22 % proteins 5 % of a stronger-smelling bitter fixed oil.
Alkaloides	Trimethylamine, Neurin, Trigonelline, Choline, Gentianine, Carpaine and Betain
Amino acids	Isoleucine, 4-Hydroxyisoleucine, Histidine, Leucine, lysine, L-tryptophan, Argenine.
Saponins	Graecunins, fenugrin B, fenugreekine, trigofoenosides A-G
Steroidal sapinogens	Yamogenin, diosgenin, smilagenin, sarsasapogenin, tigogenin, neotigogenin, gitogenin, neogitogenin, yuccagenin
Fiber	Gum, neutral detergent. Fiber

1.2 Problem Statement

When transporting liquids through pipelines there is a pressure drop in the pipelines. This pressure drop causes the increase in pumping cost. The overcome these problems there are several conventional methods being used. One of them is using drag reducing agents in pipelines. These drag reducer are injected into pipelines and only small amount of them is needed to reduce the pressure drop. The drag reducing agents that are commercially used are made synthetically. These synthetic drag reducers are expensive and can be harmful to the environment. As an alternative way to solve this problem natural drag reducing agent has been found. This can save energy and be environmental friendly.

1.2 Objective

The objective of this experiment is;

1. To study the effect of HALBA mucilage that act as a natural polymer in reducing the pressure drop in aqueous media flow through pipelines.

2. To produce an environmentally friendly Drag Reducing Agent.

1.3 Scope of Research

As a way to accomplish the objective of this study, the scope of this research focuses on how efficient the natural polymer can reduce the pressure drop in pipelines. In this research, HALBA seed mucilage is used as the natural drag reducing polymer. The methods used in the extraction of the mucilage from HALBA seed, the grafting of the natural polymer and testing the efficiency of the natural polymer in reducing the pressure drop in pipelines.

1.4 Significance of the Study

In this study, HALBA mucilage is used as a natural drag reducing agent polymer. This natural polymer concept will be used to reduce the pressure drop in pipelines. Using natural polymer is considered cost effective because the raw material is cheap and it is easy to produce. This natural polymer is also environmentally friendly because it is produced using natural herbs. Pipelines transportation will be cost effective by using this natural polymer in reducing the pressure drop.

CHAPTER 2

LITERATURE REVIEW

2.1 Flows in pipelines

Fluid flow in pipelines is commonly encountered in practice. Oil and natural gas are transported using large and long pipelines from oil reservoirs. Cooling water in an engine is transported by hoses to the pipe and to the radiator where it is cooled. Fluid flow can be classified into two that is external or internal depending whether the flow is forced over a surface or in a conduit.

There are modes of flow in pipelines. That is laminar, turbulent and transition. Laminar is characterized by smooth streamlines and highly ordered motion. Turbulent is characterized by velocity fluctuation and highly disorder motion. The transition from laminar to turbulent flow does not occur suddenly: rather, it occurs over some region in which the flow fluctuates between laminar and turbulent flow before it becomes fully turbulent. [15]

The types of flow can be seen by injecting a dye streak into the flow in a glass pipe. If the dye streak forms a straight and smooth line at low velocity then it is laminar flow. If there is bursts of fluctuations in the transitional regime and zig zags rapidly and randomly then it is fully turbulent flow.

2.2 Types of flow

The type of flow occurring in a fluid in a channel is important in fluid dynamics problems. When fluids move through a closed channel of any cross section, either of two distinct types of flow can be observed, according to the conditions present. These two types of flow can commonly be seen in a flowing open stream or river. When the velocity of flow is slow, the flow patterns are smooth. However, when the velocity is quiet high, an unstable pattern is observed, in which eddies or small packets of fluid particles are present, moving in all directions and at all angels to the normal line of flow. [6]

The flow at low velocities, where the layers of fluid seem to slide by one another without eddies or swirls being present, is called laminar flow. The second type of flow, at higher velocity, where eddies are present giving the fluid a fluctuating nature, is called turbulent flow. The existence of laminar and turbulent flow is most easily visualized by the experiments of Reynolds. Water was allowed to flow at steady state through a transparent pipe with the flow rate controlled by a valve at the end of the pipe. A fine, steady stream of dyed water was introduced from a fine jet as shown and its flow pattern observed. At low rates of water flow, the dye pattern was regular and formed a single line or stream similar to a thread. There was no lateral mixing of the fluid, and it flowed in streamlines down the tube. By putting in additional jets at other points in the pipe cross section, it was shown that there was no mixing in any parts of the tube and the fluid flowed in straight parallel lines. This type of flow is called laminar or viscous flow. As the velocity was increased, it was found that at a definite velocity the thread of dye became dispersed and the pattern was very erratic. This type of flow is called as turbulent flow.

The transition from laminar to turbulent in tubes is not only a function of velocity but also of density and viscosity of the fluid and the tube diameter. These variables are combined into the Reynolds number, which is dimensionless:

$$Re = \frac{\rho VD}{\mu}$$

Where N_{Re} is the Reynolds number, D the diameter in m, ρ the fluid density in kg/m^3 , μ the fluid viscosity in Pa.s , and v the average velocity of the fluid in m/s.

2.2.1 Laminar

Laminar flow occurs when the Reynolds number is ≤ 2300, and that the flow is fully developed if the pipe is sufficiently long so that the entrance effects are negligible. The resistance to flow in a liquid can be characterized in terms of the viscosity of the fluid if the flow is smooth. In the case of a moving plate in a liquid, it is found that there is a layer or laminar which moves with the plate, and a layer which is essentially stationary if it is next to a stationary plate.

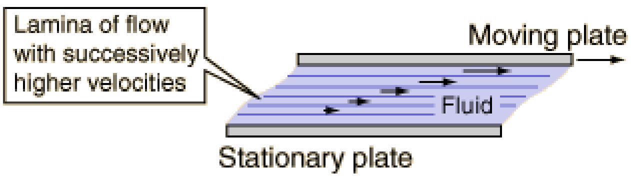

Figure 2.1: Laminar Flow

There is a gradient of velocity as you move from the stationary to the moving plate, and the liquid tends to move in layers with successively higher speed. This is called laminar flow, or sometimes "streamlined" flow. Viscous resistance to flow can be modeled for laminar flow, but if the lamina break up into turbulence, it is very difficult to characterize the fluid flow.

The common application of laminar flow would be in the smooth flow of a viscous liquid through a tube or pipe. In that case, the velocity of flow varies from zero at the walls to a maximum along the centerline of the vessel. The flow profile of laminar flow in a tube can be calculated by dividing the flow into thin cylindrical elements and applying the viscous force to them. [22]

2.2.2 Turbulent

Flow descriptions such as Poiseuille's law are valid only for conditions of laminar flow. At some critical velocity, the flow will become turbulent with the formation of eddies and chaotic motion which do not contribute to the volume flow rate. This turbulence increases the resistance dramatically so that large increases in pressure will be required to further increase the volume flow rate. Experimental studies have characterized the critical velocity for a long straight tube in the form [20]

$$v_{critical} = \frac{\mathfrak{R}\eta}{2\rho r}$$

η = viscosity in poise

ρ = density

r = radius

R= Reynolds number

2.2.3 Transition

Transitional flow occurs between laminar and turbulent flow. The transition from laminar to turbulent flow does not occur suddenly; rather it occurs over some region in which the flow fluctuates between laminar and turbulent flows before it becomes fully turbulent. The transition from laminar to turbulent flow depends on the geometry, surface roughness, flow velocity, surface temperature and type of fluid. [22]

2.3 Friction and Energy Loss

The frictional resistance to which a fluid is subjected as it flows along a pipe creates a continuous loss of energy or total head as the fluid moves downstream. Figure 1 below illustrates this by the difference in manometer levels between stations A and B. If these manometers are open to the ambient and *l* denotes the distance between A and B, the height *h* represents the static pressure drop occurring along this length. If *V* is the mean velocity in the pipe (which remains constant for a pipe of fixed cross section), and *D* is the pipe inner diameter, the friction factor *f* is defined by The Reynolds number is given by where *Q* denotes the volume flow rate, and μ the fluid viscosity. The Reynolds number determines whether the flow is laminar or turbulent. For typical flows in smooth pipes, laminar flow conditions correspond to Re<2100, while turbulent flow corresponds to Re>4000. The laminar/turbulent transition regime corresponds to 2100<Re<4000. It is noted, however, static pressure loss due to friction along a pipe. The transition values of Re from one regime to the other depend on the smoothness of the pipe. When a liquid flows through a pipeline, shear stresses develop between the liquid and the pipe wall. This shear stress is a result of friction, and its magnitude is dependent upon the properties of the fluid, the speed at which it is moving, the internal roughness of the pipe, the length and diameter of pipe. Friction loss, also known as major loss, is a primary cause of energy loss in a pipeline system. Friction losses are given by the Darcy equation. [21]

$$h_f = \frac{4fLu^2}{2gd}$$

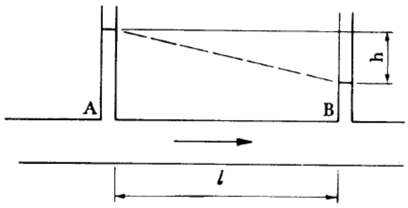

Figure 2.2: Difference in manometer levels between stations A and B

2.4 Drag reduction

Drag reduction is a flow phenomenon by which small amount of additives, e.g. a few parts per million (ppm), can greatly reduce the turbulent friction factor of a fluid. The aim for the drag reduction is to improve the fluid-mechanical efficiency using active agents, known as drag reducing agents (DRA). In multiphase flow, percent drag reduction (%DR) is defined as the ratio of reduction in the frictional pressure drop when the flow rates are held constant to the frictional pressure drop without DRA, multiplied by 100, as shown in Eq. (1). [5]

$$\%\mathrm{DR} = \frac{\Delta p\mathrm{f} - \Delta p\mathrm{fdra}}{\Delta p\mathrm{f}}\ X\ 100 \quad (1)$$

In this equation

p_f is the pressure drop in the absence

p_{fdra} is the pressure drop in the presence of DRA

2.5 Drag reducing agent (DRA)

Drag reducing agent were first documented in the middle of this century. Drag reducing agents are long chain or high molecular weight polymers that are suspended in a solvent. These drag reducing agents interacts with small scale flow disturbance that developed into large scale turbulent structures when injected into pipelines. These interactions will reduce the amount of turbulent flow in pipe and results in reduction in the frictional pressure loss in pipelines. [14]

Drag reducing agents can be divided into three groups: polymers, surfactants and suspended fibers. Polymers are long chain hydrocarbons. The long chain polymer DRAs are broken up in the regions of flow where high shear is present such as pumps or through pipe sections with numerous elbows. Once broken up these types of DRA no longer exhibit any significant drag reduction. There are new types of DRA which are able to reform after passing through regions of high shear. These types of DRA do exhibit drag reduction effects after with high shear flow. Surfactants are used to reduce the surface tension of liquid. Suspended solids are long cylinder like object with high length to width ratio. They oriented themselves in main direction of the flow to reduce drag. The most important requirement of DRAs is they must be soluble in the liquid. [6]

2.5.1 Advantage of DRA

Capacity can be increased by installing more pipeline system, by installing parallel pipe sections or by increasing the diameter of the mainline pipe. The installation of new pumping facilities or additional pipe is capital intensive and is a time consuming process. A DRA injection installation, in its simplest form, consists of an injection tap, an injection pump, and a DRA storage tank. This typically requires a much smaller capital investment and can be quickly installed at almost any existing facility. The DRA injection equipment can also be easily relocated to other locations should operational needs change in the future. Since DRA injection equipment can be deployed quickly, it can be used to provide short term increases in capacity if required. DRA can be used selectively. It can be injected into specific commodities and at specific rates to meet the required goals of increased capacity and improved operating costs. [6]

2.5.2 Disadvantages of DRA

Unlike other methods of increasing capacity such as increasing pumping power or increasing the effective pipe diameter, the increase in capacity is gradual as the DRA is injected into the pipe segment. The full effect of the DRA in a pipe segment is not realized until all the fluid in the pipe segment contains the required concentration of DRA. DRA is destroyed when it passes through high shear devices like pumps and therefore must be injected in every pipe sections where the frictional pressure loss is significant and provides no significant benefits in pipe sections where the primary losses are gravitational losses. With deregulation in the energy sector and real time negotiation of energy costs optimizing the use of DRA in terms of locations, injection rates, and scheduling may become quite difficult. The use if DRA may not be allowed in certain products such as aviation fuel so commodity scheduling may need to change to avoid potential contamination. [6]

2.6 Types of Drag Reducing Agents (DRA)

2.6.1 Polymers

Polymers used in drag reduction are two broad types: Water soluble and oil soluble. Some water soluble polymers include polyethylene oxide. Some oil soluble polymers include polymethyl methacrylate. Polymer can divide into two parts, natural polymer and synthetic polymer. Synthetic polymers can be tailor made by controlling molecular weight, molecular weight distribution, the structure of polymers and the nature and percentage of ionic groups. Natural polymers, mainly polysaccharides, are biodegradable, cheap, fairly shear stable and easily available from reproducible agricultural resources. The biodegradability of natural polymers reduces their shelf-life and needs to be suitably controlled. [15]

2.6.2 Surfactants

Surfactants are surface active agents which are the main constituent in soaps and detergents. Apart from the classical soaps, which are the alkaline salts of higher fat acids, new surfactants have been synthesized over the years, which also consist of a polar (hydrophilic) head and non-polar (hydrophobic) tail. Depending on the electrical charge of the head group, the surfactants can be classified as anionic, cationic, nonionic and zwitterionic. It is found that the effect of surfactant on the pressure drop varies, depending on the flow regime.